Comparison of Eversion Carotid Endarterectomy and Patch Carotid Endarterectomy: A Retrospective Study of 6 Years of Experience

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Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: The aim of this study was to compare early and long-term results of eversion carotid endarterectomy (e-CEA) and patch carotid endarterectomy (p-CEA).

Material/Methods: In a retrospective study, we collected data on 441 patients who underwent CEA (e-CEA=211 *vs.* p-CEA=230) between October 2009 and October 2015 at our institute. Economic costs, postoperative hospital days, use of shunts and antibiotics, early (30-day) complications, long-term restenosis, and mortality rates were compared between groups during 4 to 76 months of follow-up.

Results: Patients in the p-CEA group had a significantly higher percentage of antibiotic use (58.3% *vs.* 27%, respectively; P<.0001) and shunt use (86.6% *vs.* 16.1%, respectively; P<.0001), longer postoperative hospital stay (7.23±0.25 days *vs.* 6.38±0.20 days, respectively; P<.009) and a higher medical cost (24110±1058 ¥ *vs.* 17257±747.6 ¥, respectively; P<.0001). The perioperative complications including stroke or transient ischemic attack, cranial nerve injury, and infection/bleeding showed no difference between the 2 groups (all P>0.05). Long-term complication, including stroke or heart attack, recurrent stenosis rate, and mortality rate, showed no difference between the 2 groups (all P>0.05). Kaplan-Meier analysis shows that the recurrent stenosis-free and survival rates were not significantly different between the 2 groups (P=0.867, P=0.177, respectively).

Conclusions: The adverse event rates of perioperative and long-term follow-up showed no significant difference between the e-CEA and p-CEA groups. Both e-CEA and p-CEA are effective for carotid artery stenosis.

MeSH Keywords: **Carotid Stenosis • Cost-Benefit Analysis • Endarterectomy, Carotid**

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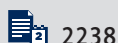
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Background

Carotid endarterectomy is the operation of choice for patients with symptomatic carotid stenosis and should also be considered for asymptomatic high-grade carotid stenosis [1]. According to the current Grade A recommendations of the European Society for Vascular Surgery (ESVS), surgical intervention is the treatment of choice for symptomatic patients with >70% and may be the best intervention for those with >50% (according to the North American Symptomatic Carotid Endarterectomy Trial; NASCET) stenosis. Surgery should be considered for asymptomatic men younger than 75 years with 70–99% NASCET stenosis, provided that the risk of surgery-related death is less than 3% [2].

The surgical options consist of conventional (c-CEA), carotid endarterectomy with patch closure (p-CEA), and eversion carotid endarterectomy (e-CEA). The first 2 include a standard longitudinal carotid arteriotomy and e-CEA with an oblique transection and eversion of the internal carotid artery [3,4]. Noticeably, both p-CEA and e-CEA are preferable to c-CEA [5], but it is unclear which is better. Several studies showed that p-CEA and e-CEA are equally efficacious surgical approaches for extracranial carotid occlusive disease [6,7] and studies that compared the influence of e-CEA and p-CEA on postoperative blood pressure had varied conclusions [8,9]. Therefore, it remains difficult to choose the optimal endarterectomy technique. Additionally, we did not find studies that evaluated the indicators of health economics in terms of medical cost, antibiotic and shunt use, or length of hospital stays. Therefore, we conducted the present retrospective study of e-CEA vs. p-CEA.

Matreial and Methods

Patients

After Institutional Review Board approval, a retrospective review was performed between October 2009 and October 2015. All patients undergoing CEA at our academic institution were included (404 patients, 441 operations) and were divided into e-CEA (n=211 operation) and p-CEA (n=230 operation) groups. All patients could be identified by access information during data collection.

Operative information

Both p-CEA and e-CEA were available during the study period. p-CEA was more commonly used for long and severe lesions and e-CEA was preferred by experienced surgeons. Preoperative data included age, sex, hypertension, coronary heart disease, diabetes mellitus, hyperlipidemia, hyperhomocysteinemia (HCY), prior cardiac/carotid surgery, vascular lesions above the aortic

arch, and a history of cerebral infarction, including stroke or transient ischemic attack (TIA).

All operations were performed under general anesthesia and blood pressure was monitored continuously. The intracranial blood flow was detected by transcranial Doppler when the carotid artery was clamped. An intraluminal shunt was selected for patients whose stump pressure was <40 mm Hg or if the intracranial blood flow obviously decreased during carotid clamping. Shunts were more inclined to be used for p-CEA patients who were expected to experience longer operative and carotid clamping time than the e-CEA patients. Intravenous heparin (5000 U) was administered to all patients before carotid clamping. Intraoperative data, including the systemic and stump pressures, clamping time, and type of carotid closure, were recorded.

Postoperative follow-up

After the operation, all patients were monitored for 12 h in the vascular ward to treat pressures lower than preoperative levels (10–20% lower). All patients received aspirin (100 mg once daily) pre- and postoperatively and were usually not discharged until the blood pressure was well controlled. When patients were discharged, we recorded the use of a shunt and antibiotic, length of postoperative hospital stay, and treatment cost. Treatment costs for in-patient carotid endarterectomy included surgery fees, nursing fees, examination fees, and medical fees.

To assess the postoperative results, we investigated the patency of the reconstructed arteries and major complications, including bleeding, infection, cranial nerve injury, stroke, and death related to intervention. Restenosis was defined as over 50% stenosis of the lumen. Early complications consisted of all of the events that occurred within 30 days after the intervention, and late outcomes occurred more than 30 days after the operation. We routinely examined patients in the outpatient setting by duplex ultrasound imaging, and all patients were contacted by telephone. In order to control bias, all data were independently checked by 2 doctors.

Statistical analysis

Binary demographics (sex), baseline risk factors, and outcome variables (shunt, antibiotic, and complications) were compared between the treatment groups using the χ^2 test.

Continuous demographics (age) and outcome variables (postoperative hospital stays, treatment cost) were summarized using the mean ± standard deviation and were compared between groups using the t test.

Table 1. Patient demographics.

Variable	e-CEA (n=211)	p-CEA (n=230)	P value
Age (mean ±sd), years	66.41±7.96	66.90±8.69	0.536
Male	81.0%	80.0%	0.783
Hypertension	72.0%	67.8%	0.336
Diabetes	31.3%	40.0%	0.069
Coronary heart disease	24.2%	23.5%	0.865
Hyperlipidemia	21.3%	45.7%	0.031
Hyperhomocysteinemia	4.7%	3.5%	0.504
Previous cerebral infarction	28.4%	30.4%	0.646
Previous cardiac/carotid surgery	9.5%	7.8%	0.537
Vascular lesions above the aortic arch	15.2%	20.9%	0.120

* p-CEA, patch carotid endarterectomy; ** e-CEA, eversion carotid endarterectomy; *** sd, standard deviation. **** P<0.05 has statistic significance.

Survival and restenosis-free proportions were calculated and are presented using Kaplan-Meier survival curves. The log-rank test was used to test differences between groups in the event-free curves.

All statistical tests were 2-sided with a 5% significance level. Analyses were performed with SPSS 20 and GraphPad Prism 5.

Results

Clinical characteristics

The patient demographics are shown in Table 1. Groups were similar in terms of age, sex, and cardiovascular risk factors, except for a higher proportion of hyperlipidemia (45.7% vs. 21.3%; P=.031) in the p-CEA group. Additionally, when we analyzed the data, 80% of the high-risk patients were men and 92.3% were older than 60 years of age. Additionally, most people had 1 or more risk factors and only 8% of patients were free from risk factors.

Indictors of health economics

Patients in the p-CEA group had a significantly higher proportion of antibiotic use (58.3% vs. 27%, respectively; P<.0001, Figure 1A) and shunt use (86.6% vs. 16.1%, respectively; P<.0001, Figure 1B) than in the e-CEA group. Additionally, the p-CEA group had longer postoperative hospital stays (7.23±0.25 days vs. 6.38±0.20 days, respectively; P<.009, Figure 1C) and a higher treatment cost (24110±1058 ¥ vs. 17257±747.6 ¥, respectively; P<.0001, Figure 1D).

Early complications (≤30 days)

Early complications are shown in Table 2. The 2 groups had no significant difference in terms of early complications. Local cranial nerve injury included injury to the superior laryngeal nerve, recurrent laryngeal nerve, hypoglossal nerve, and glossopharyngeal nerve. All patient nerve symptoms were relieved after months of recovery. Additionally, we compared the total complications, including infection, bleeding, stroke, and cardiac events, between the 2 groups and found that they were similar (3.11% vs. 2.89%, P=.649).

Long-term outcome

Follow-up data were available for 372 cases (e-CEA=179; p-CEA=193) with a mean follow-up period of 31.68±18.02 months. The long-term complications in the e-CEA and p-CEA groups were similar for stroke (3.35% vs. 2.07%, P =.446) and cardiac events (1.68% vs. 5.18%, P=.066). Additionally, we analyzed the risk of long-term complications and found that 76.92% of stroke patients had experienced a previous stoke and 93.3% of cardiac events patients had previous coronary heart disease or hypertension. Therefore, patients with a previous stroke, coronary heart disease, or hypertension may have a higher probability of complication rates and require more attention.

Recurrent stenosis >50% was found in 17 postoperative arteries (5.31%): 8 (5.30%) in the e-CEA group and 9 (5.33%) in the p-CEA group. In 76.47% (13/17), restenosis occurred within 2 years. According to the Kaplan-Meier curves (Figure 2), the restenosis-free rates were similar in the 2 groups (P=.867).
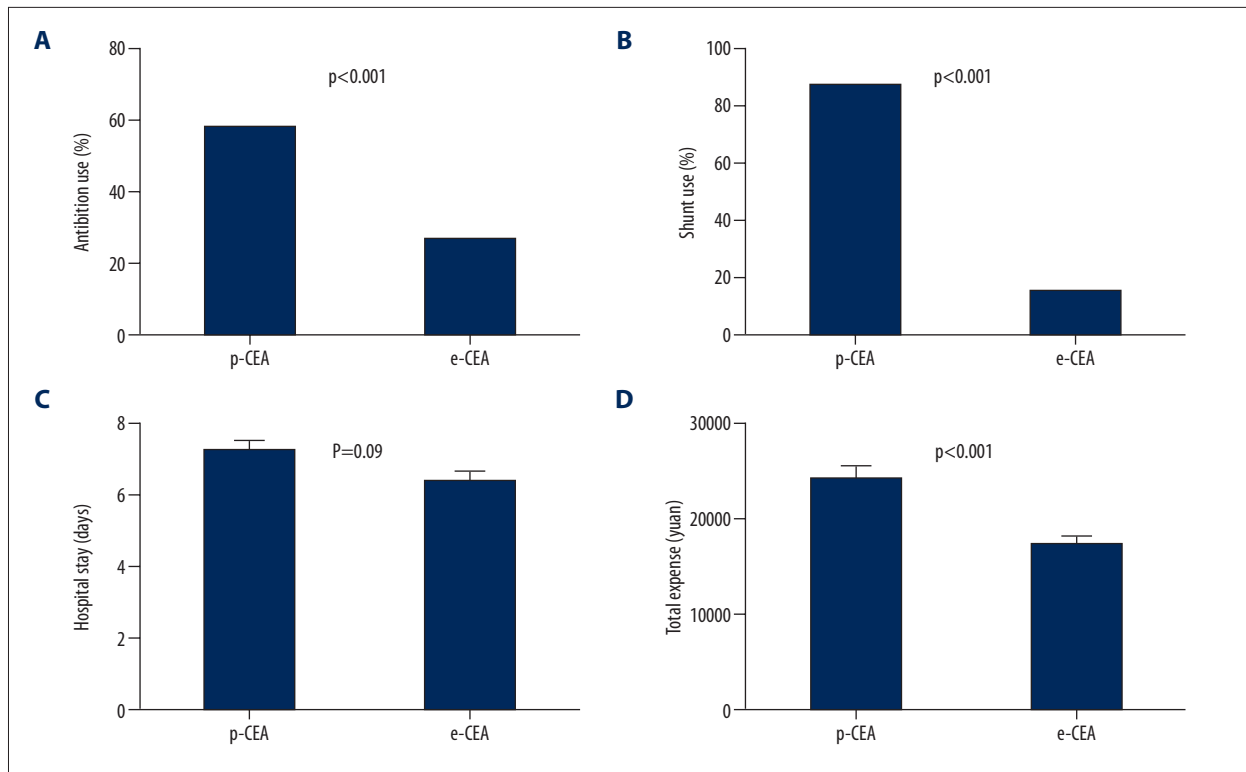
Figure 1. Comparison of p-CEA and e-CEA groups. (**A**) Antibiotic use; (**B**) Shunt use; (**C**) postoperative hospital stay; (**D**) total expenses. P<.05 denotes a significant difference.

Table 2. Early complications.

Complications (≤30 days)	e-CEA (n=211)	p-CEA (n=230)	P value
Local cranial nerve injury	11	8	0.381
Infection	0	2	0.172
Bleeding	2	3	0.715
Stroke	2	1	0.519
Cardiac events	1	1	0.957

* Data are presented as n; ** P<0.05 has statistic significance.

There were 4 patient deaths during follow-up: 3 (1.99%) in the e-CEA group and 1 (0.06%) in the p-CEA group. One died from heart attack, and 3 died from stoke. According to the Kaplan-Meier analysis (Figure 3), the cumulative survival rates for e-CEA and p-CEA groups were not significantly different (P=.177).

Discussion

Special attention for CEA patients

The management of postoperative blood pressure is very important to avoid hyperperfusion syndrome, which is one of the most feared complications of carotid artery surgery [10]. In our study, all patients were expected to be discharged after the blood pressure was relatively steady, which usually needs about 1 week. Our data show that p-CEA group had longer postoperative hospital stays, indicating that the e-CEA patients experience a better postoperative recovery. The situation is similar to that reported by Ben Ahmed [8], whose study showed postoperative blood pressure was more stable in the e-CEA group, but different from the findings reported by Demirel [9], and further research is needed on this topic. Additionally, we analyzed the relationship between long-term complications and the cardiovascular risk factors and found that 76.92% of stroke patients had experienced a prior stoke, while 93.3% of cardiac event patients had experienced previous coronary heart disease or hypertension. Therefore, patients with previous stroke,
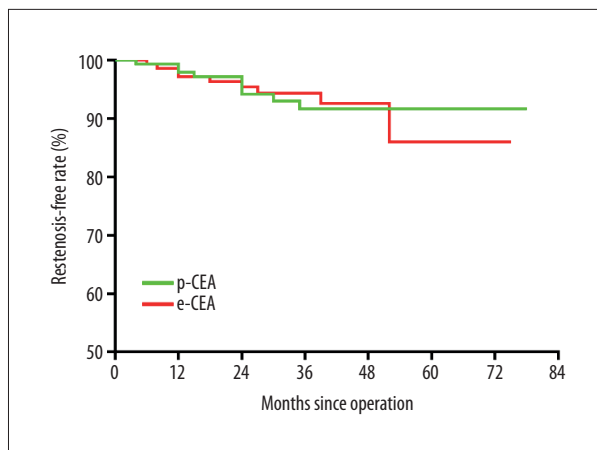
Figure 2. Kaplan-Meier analysis of the restenosis-free rates. The log-rank test showed P=.867.

Figure 3. Kaplan-Meier analysis of the survival rates. The log-rank test showed P=.177.

coronary heart disease, or hypertension should receive more attention to prevent cerebral or cardiac events.

Antibiotic use and infection

Naylor reported that 0.5–1% of patients undergoing carotid endarterectomy with prosthetic patch closure of the arteriotomy develop patch infection [11]; the most common infecting organisms are *Staphylococci/Streptococci* (90%), which should be considered when planning antibiotic therapy before cultures are available [12,13]. In our study, 0.87% of patients had an infection in the p-CEA group and 0% in the e-CEA group within the first 30 postoperative days. Though the infection rate of both groups was low, patients in the p-CEA group had a significantly higher proportion of antibiotic use (58.3% *vs.* 27%, respectively; P<.0001). The main reason for this huge difference in antibiotic use between the groups is that the antibiotic use was preventive instead of therapeutic in our study. It is clear that p-CEA carries a higher risk for path infection, which can lead to serious adverse events; therefore, there was more preventive use of antibiotics in the p-CEA group. For our 2 infection cases, one was treated with antibiotic irrigation and the other was treated with patch excision and autologous reconstruction. At present, patch excision and autologous reconstruction remains the criterion standard. Although the infection rates were similar in the 2 groups, the p-CEA group needed the higher use of preventive antibiotics than the e-CEA group.

Is a shunt necessary?

The maintenance of continuous brain perfusion during CEA is vital to protecting the brain from ischemic injury. The use of a shunt during the cross-clamping stage of the procedure ensures adequate cerebral perfusion. The use of a shunt has many potential disadvantages, including dislodgement and air or plaque embolism, requiring extra time for insertion and
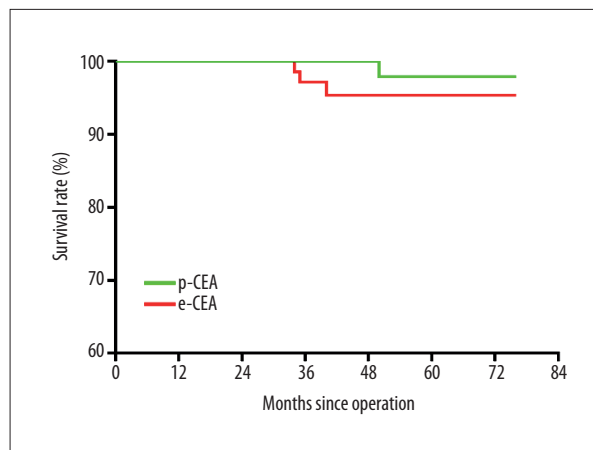
removal, longer arteriotomy, and poor cost effectiveness [14]. One study included 122 consecutive patients with a mean procedure time of 170 min in patients in whom a shunt was used compared with 100 min in patients without a shunt (P=0.003) [15]. Another study of 59 patients showed that conventional use of a carotid shunt tube in carotid endarterectomy (CEA) for extracranial carotid stenosis treatment does not reduce the risk of perioperative complications [16]. A recent review showed that the use of routine shunting and selective shunting was associated with a low stroke rate. Both methods are acceptable, and surgeons should select the method with which they are more confident [17]. In our study, patients in the e-CEA group had a significantly lower proportion of shunt use (86.6% *vs.* 16.1%, respectively; P<.0001) than in the P-CEA group, but they did not have higher perioperative CH and CHS rates. Therefore, e-CEA can effectively reduce the use of shunts without increasing the CH and CHS rates. Shunts should be selectively used in cases with bilateral severe carotid artery occlusive disease or in patients who developed neurological symptoms with carotid artery clamping. Our previous study showed that the proportion of bilateral carotid artery lesions was similar [18], which is inconsistent with the proportion of shun use between the 2 groups in the present study. In the operative section, we showed the expected operation time and carotid clamping time are very important factors influencing the use of shunts, and p-CEA clearly required longer more operation time and carotid clamping time than with e-CEA, which may be the main reason for significantly higher shunt use in p-CEA patients.

Which method should be chosen?

The rate of perioperative complications and long-term outcomes in our study were statistically similar in the e-CEA and p-CEA groups. Our results are supported by a previous report showing that perioperative outcome measurements in the

e-CEA *vs.* p-CEA group included stroke or a transient ischemic attack (1.56% *vs.* 1.6%, respectively) and cranial nerve injury (3.13% *vs.* 2.4%, respectively) [7]. Local cranial nerve injury was the most common complication in the early stage, but most patients achieved relief with little effect on their quality of life. Several studies have shown that e-CEA and p-CEA are equally effective surgical approaches for extracranial carotid occlusive disease in terms of the long-term results [19]. We found that 76.47% (13/17) of restenosis occurred within 2 years, which agrees with a review of 7 studies reporting on 2317 procedures and demonstrates that most restenosis usually occurs in the early stage [20]. Additionally, e-CEA obviously shortened the postoperative hospital stays by approximately 0.85 days and reduced the medical expenses by approximately 6853 ¥. These factors may benefit from the lower use of shunts and antibiotics.

In view of these results and a critical analysis of the current literature, there are slight advantages for e-CEA over p-CEA despite the equivalent surgical results. Of note, e-CEA is a suitable procedure with appropriate intraoperative control in the hands of an experienced surgeon.

There were several limitations in this retrospective case control study. Some data, such as contralateral carotid lesion and carotid plaque pathological, were incomplete, so the related data could not be analyzed in this study. In addition, our patients came from all over China, which increase the difficulty of follow-up (15.6% of the study patients were lost to follow-up). Our study results might have been influenced by these limitations, and more clinical data are needed for more significant analysis.

Conclusions

The adverse event rates of perioperative and long-term follow-up showed no significant difference between the e-CEA and p-CEA groups. e-CEA and p-CEA are both effective treatments for carotid artery stenosis.

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